DOI:
10.1080/17437199.2017.1339568

Document Version
Peer reviewed version

Evaluating the impact of method bias in health behaviour research: A meta-analytic examination of studies utilising the theories of reasoned action and planned behaviour.

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We thank Megan Andrews, Madalyn Oliver, Alexander Svenson and Celeste Coltman for help in screening the literature, data extraction and coding. We also thank Murad Safadi for designing and maintaining the database used to handle extracted data. This research was supported under the Australian Research Council's *Discovery Projects* funding scheme (project number: DP130100068). The ARC had no role in the collection, analysis and interpretation of data, or the right to approve the finished manuscript prior to publication.

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Abstract

The methods employed to measure behaviour in research testing the theories of reasoned action/ planned behaviour (TRA/TPB) within the context of health behaviours have the potential to significantly bias findings. One bias yet to be examined in that literature is that due to common method variance (CMV). CMV introduces a variance in scores attributable to the *method* used to measure a construct, rather than the construct it represents. The primary aim of this study is to evaluate the impact of method bias on the associations of health behaviours with TRA/TPB variables. Data is sourced from four meta-analyses (177 studies). The method used to measure behaviour for each effect size was coded for susceptibility to bias. The moderating impact of method type was assessed using meta-regression. Method type significantly moderated the associations of intentions, attitudes and social norms with behaviour, but not that between perceived behavioural control and behaviour. The magnitude of the moderating effect of method type appeared consistent between cross-sectional and prospective studies, but varied across behaviours. The current findings strongly suggest that method bias significantly inflates associations in TRA/TPB research, and poses a potentially serious validity threat to the cumulative findings reported in that field.

Keywords: Health behaviour; health behaviour theory; method bias; meta-regression.

Evaluating the impact of method bias in health behaviour research: A meta-analytic examination of studies utilising the theories of reasoned action and planned behaviour.

The methods employed to measure both behaviour and its antecedents have the potential to significantly bias observed scores as well as the associations between observed scores. A participant's response on a given measure is comprised of two non-random components: one representing the effect of the latent variable that the measure represents and the other representing biases resulting from the effects of various measurement artefacts. The existence of those biases, here termed *method bias*, is problematic as they potentially provide an explanation for the observed associations other than those hypothesised by researchers (P. M. Podsakoff, MacKenzie, Lee, & Podsakoff, 2003; Sharma, Yetton, & Crawford, 2009). One such method bias that has received considerable attention in the behavioural sciences is that due to common method variance (CMV), which is variance in an observed score that is attributable to the method used to measure a construct, rather than the latent construct that a particular measure represents (P. M. Podsakoff et al., 2003).

Four potential sources of CMV have been proposed: where both predictor and criterion variables are collected using a *common source or rater*; *item characteristics*, for example item complexity or ambiguity; *item context*, for example the position of an item in a questionnaire relative to other items; and *measurement context*, for example the time and location of measurement. Each of these sources is held to produce CMV through eliciting different psychological processes in the respondent. A full discussion of these is beyond the scope of this article (a detailed analysis is available in P.M. Podsakoff et al., 2003), however, some relevant examples for the current study are as follows. First, items may be ambiguous and not well understood by participants. This can lead to systematic responding, for example using a heuristic such as by responding neutrally, leading to biases in observed associations between ambiguous predictor and criterion variables. Ambiguity can occur in any part of a scale, primarily due to poor wording, but can also result from the behaviour of interest (for example,

broad behavioural categories, such as physical activity, may be less well understood than more specific examples such as fruit and vegetable consumption) or the measurement scale used (for example, use of a Likert scale to measure frequency of a behaviour as opposed to allowing participants to provide an unprompted frequency of behaviour). CMV between two variables can also occur when both predictor and criterion variables are measured in the same context (i.e. at the same time, in the same location) as this provides common contextual cues which can influence the retrieval of information from memory.

It has long been accepted that the method of measurement biases empirical findings (Campbell & Fiske, 1959; P. M. Podsakoff, MacKenzie, & Podsakoff, 2012). However, prior research suggests that there is a wide variation in the magnitude of method bias across different constructs and fields of research (Cote & Buckley, 1987). This has led to calls for assessments of the extent of method bias within specific theoretical domains (P. M. Podsakoff et al., 2003). The potential effects of method bias and the implications of that bias for empirical findings are rarely raised in health behaviour research (although see Conner, Norman, & Bell, 2002; Conner, Warren, Close, & Sparks, 1999).

There are strong reasons to believe that studies examining the association between the Theories of Reasoned Action (TRA) (Fishbein & Ajzen, 1975)/ Planned Behaviour (TPB) (Ajzen, 1991) and health behaviour may be susceptible to method bias. Guidelines for measuring these models (Ajzen, 2002; Fishbein & Ajzen, 2010; Francis et al., 2004) typically recommend a multi-phase approach to scale development including accurate specification of the population and behaviour of interest, preliminary qualitative studies to determine item content, pilot-testing scales and re-wording items if necessary. Some of these steps could serve to reduce the potential for method bias, for example rigorous pilot testing could ensure items are less ambiguous and readily understood by participants. However, as has been mentioned in previous studies (Courneya, 1994; Kaiser, Schultz, & Scheuthle, 2007) others are likely to have the opposite effect, in particular, the requirement for antecedent and criterion items to adhere to

the principle of *scale compatibility* (Fishbein & Ajzen, 2010). Scale incompatibility is considered to attenuate correlations and occurs when different measurement scales are used for antecedent constructs and behaviours, for example intentions measured using a Likert scale and behaviour measured using a free-text estimate of frequency. However, the method bias literature provides an alternative view. That is, rather than increasing the accuracy of measurement between variables, using the same rating scale for predictor and criterion items could have the opposite effect by leading participants to implicitly link the two items regardless of content, thus artificially inflating the association between the two variables. Indeed, the theoretical literature on minimising method biases recommends scale non-correspondence as a procedural remedy for reducing method bias (P. M. Podsakoff et al., 2003).

The multitrait-multimethod (MTMM) technique (Campbell & Fiske, 1959) has long been held as the gold standard for evaluating the effect of method bias (Doty & Glick, 1998). A key insight underpinning the MTMM technique is that variability in methods that are *a priori* susceptible to varying levels of method bias is essential to evaluating the extent of method bias within a study. However, the MTMM technique requires researchers to have designed variation in methods and traits within the original studies, which excludes much of the research conducted in the behavioural sciences. Extending the key insight of the MTMM technique, Sharma et al. (2009) proposed the method-method pair (MMP) technique which evaluates the extent of method bias within a field of study based on the variability in methods *between* studies. While the MTMM focuses on controlling for the effect of method bias within studies based on designed within-study variation in methods, the MMP technique employs the same rationale to focus on controlling for the effect of method bias based within a field of study on naturally occurring between-study variations in methods.

The MMP technique estimates the magnitude of method bias based on three method characteristics covering two of the three categories of sources of bias described above: data

sources (i.e. self-report vs objective, covering *common source or rater*), scale format and item abstractness (both aspects of *item characteristics*). In addition, it also enables researchers to examine differences in CMV between cross-sectional and prospective data, thus also covering a third category (*measurement context*). Different pairs of method type are held to carry an incrementally greater risk of method bias; therefore, if the observed associations between variables vary significantly by method type, then that variation is likely due to the presence of method bias. Specifically, drawing on the method bias literature (P. M. Podsakoff et al., 2003), they hypothesized that the least amount of method bias can be expected when behaviour is measured by an objective source; higher levels of method bias are expected when self-report open-ended numerical measures of behaviour are employed; even higher levels of method bias can be expected when scales with behavioural anchors are employed; and the highest amount of method bias can be expected when Likert-type scales employing perceptual anchors (e.g. agree/disagree) are employed. Given that, within the context of TRA/TPB studies, antecedent variables are almost universally assessed using perceptually anchored Likert-type scales, Sharma et al. (2009) assert that the extent of method bias in the association between these variables and behaviour will depend solely on the method employed to measure behaviour.

The rationale for this grading is explained in further detail in Sharma et al. (2009). Briefly, collecting data from an objective source is the least prone to method bias as it precludes the elicitation of the psychological processes in the respondent considered to be responsible for method bias effects (data source). Open-ended numerical scales collecting data from the same source introduce the potential for bias, but are less prone to method effects than anchored scales (either behavioural or perceptual) as these can, for example, lead participants to generate theories regarding the researchers' assumptions and respond accordingly (Schwarz, 1999). Finally, perceptual anchors requiring participants to reflect on their thoughts or feelings are considered more prone to behavioural anchors requiring participants to reflect on their own

previous behaviour as they increase the cognitive processing required of the respondent (Doty & Glick, 1998; Spector, 2006)

Sharma et al. (2009) illustrate the application of the MMP technique by estimating the magnitude of bias in the cumulative evidence in support of the technology acceptance model, an adaptation of the TRA/TPB to technology use behaviours. Based on a meta-analysis of 75 data sets, they found that the average correlation between attitudes and behaviour increased monotonically from 0.16 to 0.59 across these four levels of increasing susceptibility to method bias and accounted for 56% of the variance in reported correlations across studies. The MMP technique has also been successfully applied in different research literatures, with N.P. Podsakoff et al. (2013) finding that method type explained 45% of the variance in reported correlations across studies examining organisational citizenship behaviour. The consistency in findings across two different theoretical contexts, coupled with its strong grounding in the theory of method biases suggests that the MMP technique possesses a high degree of validity for estimating the extent of method bias within a domain of study (Bagozzi, 2011).

The primary aim of the current study, therefore, is to determine the impact of method bias on the associations between TRA/TPB variables and four different health behaviours: physical activity, dietary patterns, food choice behaviours and sun protection behaviours. We will also attempt to draw further conclusions with regard to potential sources of method bias. First, we will examine measurement context effects, by looking for differences in magnitudes of method bias between cross-sectional and prospective data. Second, we will examine any differences in the impact of method bias between each of the four behaviours: physical activity; dietary patterns; food choice behaviours and sun protection behaviours. It seems likely that the amount of cognitive processing needed to respond to measures examining broad categories of behaviour, for example dietary patterns such as healthy eating, is greater than that required for more concrete behaviours, for example food choices such as fruit consumption, thus increasing

the likelihood of the operation of psychological processes considered to drive method bias (Doty & Glick, 1998; Spector, 2006).

Method

The source of data for the current study is a series of four meta-analyses conducted by this study's authors. The aims of those meta-analyses, respectively, were to: (a) test the hypothesis that the magnitude of the association between intentions and physical activity behaviour decreases as the temporal separation between the two increases; and to examine the associations of TRA/TPB variables with (b) dietary patterns; (c) discrete food choice behaviours; and (d) sun protection behaviours. These particular behaviours were chosen as: each contributes independently to the burden of disease in Australia where this study was conducted (Australian Institute of Health and Welfare, 2016); these behaviours have been examined in numerous studies, allowing the inclusion of a sufficient number of effect sizes to have adequate power to test the main study hypotheses and; these diverse behaviours allowed us to examine differences in the impact of method bias between broad categories of behaviour and more discrete behaviours. The design, conduct and reporting of each meta-analysis was informed by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (PRISMA, Moher, Liberati, Tetzlaff & Altman, 2009). A PRISMA checklist for the current study is included as Supplementary File 1. As each study involved the secondary analysis of existing datasets, ethical approval was not sought. The funding organisation for this program of research had no role in the collection, analysis and interpretation of data, or the right to approve any of the finished manuscripts prior to publication. No study protocols were produced.

Selection criteria

The PICOS (population, intervention, comparison, outcome, study design) approach (Moher & Tricco, 2008) was used to formulate the selection criteria in each review. The health behaviours targeted in each review were as follows: (a) *physical activity* or *exercise*, defined

broadly and conducted at one's leisure as opposed to specific forms of exercise or sports training; (b) broad dietary patterns such as *healthy eating* or *eating a low fat diet*; (c) the choice of specific foods (e.g. *high fibre bread, fruit, fish*) or narrow categories of foods (e.g. *high calorie snacks, dairy products, ready meals*); (d) sun protective behaviours such as *using sunscreen, wearing protective clothing*, or *seeking shade during peak hours of the day*. Common inclusion criteria across each review were as follows: studies were included provided the population had no current or former medical conditions, as the psychological determinants of behaviour in these populations may not be generalizable to the community at large. Studies where participants received an intervention were also excluded as the receipt of intervention components could moderate the associations between variables. Studies were not selected based on any comparison between conditions. Outcomes extracted from each study varied. In review (a) studies were included in which the reported outcomes included bivariate correlations between intentions and physical activity measured at a subsequent time point. For reviews (b) to (d), in keeping with theoretical models TRA studies must at minimum have reported correlations between attitudes and subjective norms (SN) with intentions, and intentions with behaviour, whereas TPB studies must have additionally reported correlations between perceived behavioural control (PBC), intentions and behaviour. Any quantitative study design was included provided the other inclusion criteria were met. In addition, studies needed to report sample size, full details (i.e. item wording, response scale and response anchor) of at least one of the items used to measure each variable of interest and be published in the English language.

Study identification

A standardised procedure for searching and screening was used in each review. Broad scoping searches were conducted initially to focus the research question, gauge the number of eligible studies and inform the development of the formal search strategy. The results of these initial searches were then verified using a formal electronic search strategy. For each review,

we searched PsycINFO, MEDLINE (both via Ovid), Web of Science and CINAHL (via EBSCOhost) (see Supplementary File 2). We also searched ProQuest Dissertations & Theses to locate unpublished studies in order to address the 'file-drawer' problem (Rosenthal, 1979). Finally, we manually searched the reference lists of all included studies and key systematic reviews. A PRISMA flow diagram for each review can be found in Supplementary File 3.

Databases containing all titles and abstracts were screened by one author for possible inclusion. For review (a) the selected studies were screened for inclusion by one author, with the accuracy of selection checked by a second author based on a subsample of studies. For reviews (b) to (d) studies were selected for inclusion independently by two authors. Cohen's kappa for agreement on study selection ranged between and κ = .80 and .97 in these reviews.

Data extraction

To test for the impact of method bias we extracted correlation data and sample size and coded each item used to assess each antecedent variable (attitudes, SN, PBC and intentions) and behaviour using a four-point, continuous, ordinal scale capturing incremental susceptibility to method bias (Sharma et al., 2009). *System captured measures*, are the least biased and refer to data obtained from objective sources, for example accelerometer data to measure physical activity; *behavioural continuous measures*, are those in which behaviour is captured on a continuous, open-ended scale, for example "on how many occasions did you exercise over the past week?"; *behaviourally anchored measures*, are those in which actions are captured using behavioural anchors, for example "typically, how often do you exercise? (not at all to very often); finally, *perceptually anchored measures*, carry the greatest risk of bias, and involve participants' responses being captured on Likert or semantic differential scales, for example "I exercise often", captured on a scale ranging from strongly disagree to strongly agree.

To ensure inter-rater reliability for this assessment, an initial training phase was conducted. All items assessing behaviour in the first 27 studies were independently double-coded by two research assistants during the first meta-analysis conducted (physical activity) to

ensure an acceptable level of agreement. Cohen's kappa was used to determine agreement between the two raters at this stage. Agreement between the two coders was substantial (κ = .60) (Landis & Koch, 1977). The remaining studies were coded independently by one of five coders. To ensure reliability of coding, all items used to measure behaviour were double-coded in a randomly selected subset of 20% by one of the two original, trained coders. Again, agreement between coders was substantial (κ = .60).

A number of studies included in the meta-analysis comprised multiple (defined as two or more) datasets. The decision of how to handle these data was determined by the current research question and guided by Borenstein, Hedges, Higgins, and Rothstein (2009) and Sharma et al. (2009). In instances where multiple datasets were due to data being presented for independent samples (e.g. based on gender or ethnicity) or where data was presented from two or more time points using the same participants, these were treated as individual data points for analysis. In line with the aims of the current article, where studies reported data from separate measures of behaviour collected using different methodologies, for example objective and subjective measures of physical activity, each was treated as an individual data points for analysis.

Where multiple, non-independent, associations were reported (e.g. two intentions measures predicting behaviour separately (Godin, Valois, & Lepage, 1993)) a mean value was calculated to produce a single, summary association for the study. Similarly, a single mean value was also used where studies reported separate data from different measures of attitudes, e.g. instrumental and affective attitudes (e.g. Hagger & Chatzisarantis, 2005; Payne, Jones, & Harris, 2004) .

Data analysis

Calculation of the pooled mean effect size (r_+) was conducted using inverse-variance weighted random effects meta-analysis. The inverse-variance method, in which each included effect size is given a weight equal to the inverse of its variance, allows more weight to be given to more

precise studies (Borenstein et al., 2009). Funnel plots, rank correlations (Begg & Mazumdar, 1994) and regression intercept (Egger, Smith, Schneider & Minder, 1997) were used to test for publication bias. The potential impact of any publication bias was assessed using the trim and fill procedure (Duval & Tweedie, 2000). We also estimated the heterogeneity across studies, using both the *Q* (a significant result indicates significant heterogeneity (Borenstein et al., 2009) and I^2 statistics (values of 25%, 50% and 75% indicate low, moderate and high heterogeneity respectively (Higgins, Thompson, Deeks, & Altman, 2003).

Following Sharma et al. (2009), method type for each included effect size was calculated as the mean method type score of all items used to measure behaviour in that particular study. Many studies employed multiple items to measure behaviour, with not all items belonging to the same method type category. As the MMP assumes that one scale for each method pair is measured using a perceptually anchored scale, only pairs meeting this assumption were included. This allowed us to include all effect sizes where attitudes, SN and PBC were paired with behaviour, but led to the exclusion of 41 effect sizes between intentions and behaviour. All analyses were subsequently based on variability in the method type used to measure behaviour. To test for the moderating impact of method type we employed the protocol for random effects meta-regression recommended by Borenstein et al. (2009), with the correlation between each cognitive variable (attitudes, SN, PBC and intentions) and behaviour as the criterion variable, behaviour method type as the predictor variable and studies being weighted by their inverse variance weights. All analyses were performed using Comprehensive Meta-Analysis (CMA) Version 3.0 (Borenstein, Hedges, Higgins, & Rothstein, 2014).

Results

The electronic search strategies retrieved 22,940 unique records across all meta-analyses. A further 165 were identified through screening other meta-analyses and the reference lists of included studies. In total, 187 reports (159 journal articles and 28

dissertations) met the inclusion criteria. Of these, 110 examined physical activity, 22 examined dietary patterns, 46 examined food choice behaviours and nine examined sun protection behaviours. A list of all included reports can be found in Supplementary File 4. Data from 13 studies were reported in more than one article. Three articles reported data from two studies and a further four were included in more than one review (e.g. due to presenting outcomes both on food choice and physical activity). A total of 173 studies were therefore included.

The majority of these studies were conducted in western, English speaking countries with the UK producing the most (24%, n=42), followed by the USA (24%, n=41) and Canada (20%, n=36). The number of participants in each study ranged from 35-3859, with a mean *n* of 367. Basic details for each included study can be found in Supplementary File 5. Mean levels of associations between variables and behaviour are shown in Table 1. Intentions had the strongest associations with behaviour ($r_+ = 0.49$), followed by PBC ($r_+ = 0.32$), attitudes ($r_+ = 0.31$) and SN ($r_+ = 0.18$).

Although we included unpublished studies, we checked whether there was any evidence of publication bias in those studies that had been published. Examination of the funnel plots for the associations between all cognitive variables (intention, attitudes, SN and PBC) and behaviour revealed no evidence of publication bias (funnel plots are presented in Supplementary File 6). These conclusions were supported by Begg and Mazumdar's rank correlation test, and Egger's regression intercept which were both non-significant. Similarly, the trim and fill procedure (Duval & Tweedie, 2000) also failed to identify any evidence of publication bias. Examination of the *Q*-statistic and I^2, indicated significant heterogeneity for all associations (see Table 1), supporting the use of meta-regression to search for moderators such as behaviour method type.

Testing for the moderating role of behaviour method type (common source or rater/ item characteristic effects)

Our first set of analyses evaluated the impact of method bias separately for the association between each construct and behaviour through a series of random-effects meta-regression analyses. The overall associations between cognitive variables and behaviour at each level of susceptibility to method bias are shown in Table 2. As can be seen in Table 3, behaviour method type significantly moderated the associations between intentions, attitudes and SN with behaviour, but not the association between PBC and behaviour.

Comparing the impact of behaviour method type in cross-sectional and prospective associations (measurement context effects)

Following this, we examined whether behaviour method type moderated the associations between variable pairs when measured at the same point in time or prospectively. As can be seen in Table 4, the effect of behaviour method type was similar in both sets of analyses. Again, behaviour method type significantly moderated all associations, aside from those between PBC and behaviour.

Comparing the impact of behaviour method type in included behaviours

Finally, we examined the impact of method type separately within each of the four behaviours (see Table 5). Behaviour method type appears to have the greatest impact in those studies examining dietary patterns, significantly moderating associations between all variables and behaviour. In contrast, method bias appears least impactful in those studies examining food choice behaviours. Behaviour method type did not moderate any of the included associations for this behaviour.

Discussion

The primary aim of the current study was to determine the impact of method bias on the associations between TRA/TPB variables and a range of health behaviours. When we examined the associations between attitudes, SN and intentions with behaviour, the B coefficients for method type were each positive and significant, indicating that mean correlations increased as the methods used to measure the association became more susceptible

to method bias. Each level of method type added between 0.08-0.10 to the mean correlations between those variables. The current findings strongly suggest that method bias inflates observed associations between the TRA/TPB constructs and health behaviour.

These findings are in line with previous work in the organisational research field (Cote & Buckley, 1987; Sharma et al., 2009). However, they do differ significantly from a more recent study conducted by Schaller et al. (2015), who employed an alternative method, the marker variable technique, to examine the impact of method bias in over 100 articles examining the application of the TPB to a broad range of behaviours. These authors concluded that method bias was not a concern in research utilising the TPB model. However, the Schaller et al. (2015) study has a number of key limitations that the design of the current study avoids. Those limitations include the inclusion of only cross-sectional data, search strategies limited to specific journals, and the use of the marker variable technique which has been criticised for not capturing key sources of bias (P. M. Podsakoff et al., 2003; Yetton, Sharma, & Crawford, 2011). We therefore believe that the current findings are more credible.

Sources of method bias in the examined literature

We found no evidence of an impact of measurement context on reported associations. This finding is in contrast with previous research which found a difference in the effects of method bias between cross-sectional and prospective research (N. P. Podsakoff et al., 2013). Introducing a period of temporal separation between the assessment of variables has previously been recommended as a potential remedy for method bias in behavioural research (P. M. Podsakoff et al., 2003). Although there are other clear benefits for measuring a dependent variable at a time point subsequent to the assessment of an independent variable, such as to allow an attribution of causality, the results of the current study contradict the rationale for using this procedure to minimise the effects of method bias.

The results indicate that in this literature, method bias results from both common source or rater effects and item characteristic effects. Using self-report measures to gather data on

both antecedent items and behaviour is the greatest source of method bias as it facilitates the elicitation of numerous psychological processes in the respondent (e.g. consistency motifs, implicit theories, social desirability tendencies) to bias observed associations with behaviour (P. M. Podsakoff et al., 2003). The finding that using a common source to measure both predictor and criterion variables leads to higher associations between TRA/TPB variables and behaviour than using alternative sources has been observed in previous meta-analyses (Armitage & Conner, 2001; McEachan, Conner, Taylor, & Lawton, 2011).

With regard to item characteristic effects, the results indicate that assessing behaviour using rating scales with researcher-defined endpoints, either behaviourally or perceptually anchored, are more prone to bias than open-ended, continuous scales. One clear problem with the use of rating scales to assess behaviour (e.g. not at all/ very much) is that these are commonly open to interpretation compared with, for example, freely chosen numbers to rate the frequency of a behaviour, which carry a precise meaning (Courneya, 1994). It is possible, therefore, that respondents find these former measures overly ambiguous, thus introducing bias into observed scores.

Ambiguity could also play a role in explaining the observed differences in the impact of method bias between health behaviours. Behaviour method type appears to have the greatest impact in those studies examining dietary patterns, significantly moderating each association and explaining between 17% (PBC-behaviour) and 53% (SN-behaviour) of the variance in the association between cognitions and behaviour. Method bias appears least impactful in those studies examining food choice behaviours, with behaviour method type failing to moderate any of the included associations. To our knowledge, these findings are novel and warrant further research.

The two behaviours with the largest and smallest effects of method bias allow us to draw insight into what might be driving that variation. Behaviours in the dietary patterns category were complex and included such behaviours as ‘healthy eating’ or ‘eating a low fat

diet'. These can be more correctly considered as *behavioural categories* (Fishbein & Ajzen, 2010) when compared with those assessed in the food choice review, which examined behaviours such as 'eating fruit and vegetables' or 'eating high-calorie snacks'. As with the different constructs examined in this study, these behaviours can also be distinguished by their abstractness. For example, there is likely to be general agreement amongst participants as to what is meant by 'eating fruit and vegetables', whereas 'healthy eating' is more open to interpretation. Research has found interpretations of broad categories of health behaviours, such as healthy and unhealthy eating to vary widely across individuals (Povey, Conner, Sparks, James, & Shepherd, 1998). Therefore, it seems likely that the amount of cognitive processing needed to respond to measures examining such behaviours is greater than more concrete examples. It is worth noting that for food choice studies, method bias did not moderate any associations, suggesting that the abstractness of the behaviour targeted in studies may be the key driver of method bias in health behaviour research. The other two categories of behaviour are broadly supportive of this hypothesis. The behaviour that was next most prone to the effects of method bias was physical activity, another behavioural category, with behaviour method type moderating three of the four associations (intentions, attitudes and SN, explaining 10%, 15% and 10% of the variance respectively). This was followed by sun protection behaviours, which combined behavioural categories (e.g. *engaging in sun protection behaviour*), with more concrete behaviours (e.g. *regularly using SPF 15+ sunscreen*). Only two of four associations with behaviour were significantly moderated by method type for this behaviour (intentions and SN, 13% and 29% of variance respectively). Further research is needed to more fully examine this issue.

Although it was not a central focus of the current study, we also found that the impact of method bias varies across constructs, as has been reported previously (Cote & Buckley, 1987). When all behaviours were examined together, method type was found to significantly moderate the associations of intentions, attitudes and SN with behaviour. However, aside from

those studies examining dietary patterns, we found no evidence of moderation for the association between PBC and behaviour. This is an interesting finding and one worthy of further examination. It may be that, compared to attitudes, SN and intentions, perceptions of control are less abstract, and thus require less judgement and cognitive processing. According to Bandura (1997), perceptions of self-efficacy (a construct broadly analogous to PBC) are primarily gained through experience with that behaviour. Therefore, it may be that perceptions of control require less cognitive effort or judgement on the part of participants when completing measures.

Comparing method bias and TPB operationalisation issues

Current guidelines for measuring TRA/TPB variables and examining their associations with behaviour contain steps that should, in theory, create clear measures that are readily understood by participants, thus minimising the impact of ambiguous behaviours. For example, with regard to the examination of broad behavioural categories, Fishbein and Ajzen (2010) have recommended that researchers ensure that all participants have a description of and understand any behavioural category used, and that this description matches that of the investigator. Such reduction in ambiguity should improve the association between cognitions and behaviour through a minimisation of method bias. The current results suggest that the authors of these individual studies have failed to achieve this; however, it could also be that such steps are not sufficient to reduce the occurrence of method bias. To our knowledge no study has empirically examined this issue.

Furthermore, one of the implications of the current findings is that there are clear problems with these current guidelines, in particular with regard to the principle of scale correspondence. Although hypotheses drawn from the scale correspondence and method bias literatures are based on different causes and lead to different conclusions, both predict similar patterns of results and are thus difficult to contrast. Therefore, some of the results reported here could also be attributed to scale (in)compatibility. For example, both the method bias and scale

correspondence literatures would expect a method-method pair comprised of two perceptually anchored scales to yield the highest associations. Similarly, the scale correspondence thesis would also expect the association between a perceptually anchored scale measuring a cognitive antecedent and behaviour measured using a continuous scale to be lower as the variation obtained by one is not congruent with the other (Courneya, 1994). However, it is worth noting that not all of the findings followed this pattern. In particular, the varying impact of method bias across health behaviours and constructs is arguably more in line the effects of method bias, given these also vary in their abstractness. We therefore believe that the effects of method bias present a more coherent explanation for the current findings.

Perhaps most crucially, one further difference between the two positions is that the method bias literature suggests that the association produced using two perceptually anchored scales is artificially inflated by the effects of method bias. In contrast, within the TRA/TPB measurement perspective, this association is seen as more accurate as the principle of scale correspondence has not been violated. One corollary of the position based on TRA/TPB measurement guidelines is that corresponding scales should *a priori* be preferred. Given the predominant use of anchored scales to measure TRA/TPB variables (although see (Courneya, 1994; Rhodes, Matheson, & Blanchard, 2006) for alternatives) this could lead researchers to prefer assessments of behaviour based on participant self-reports using similarly scaled items. This clearly does not present an optimal solution as it would exclude many gold standard assessments of behaviour such as physical activity data captured using accelerometers or information on diet assessed using weighed food records.

Furthermore, there are also reasons to expect that these current TRA/ TPB operationalisation guidelines lead studies to be further prone to effects of method bias not covered by the current analysis. Perhaps the issue with the greatest potential for biasing associations is the principle of compatibility, described by Fishbein and Ajzen (2010) as "*perhaps the most important prerequisite for predictive validity*" (p44). The principle states

that two measures of a given disposition can be considered compatible with each other so long as their *target, action, context* and *time* elements are assessed at *identical* levels of generality and specificity. Whilst it is possible that adhering to this principle leads to higher associations due to participants being able to match their intention to enact a specific behaviour with their self-reported performance of that same behaviour, it is also possible that the resultant similarity in text between antecedent variables and behaviour are artificially inflated due to method bias (Kaiser et al., 2007). Previous research has found that text similarity between items can account for a significant proportion of variation in correlations in survey research (Arnulf, Larsen, Martinsen, & Bong, 2014; Sharma, Safadi, Andrews, Ogunbona, & Crawford, 2014).

Strengths and limitations

The current study had a number of strengths. Primary amongst these were the comprehensive search strategies employed, targeting both published and unpublished research. This led to the inclusion of a large number of articles, providing a good degree of power to test the study hypotheses across multiple variables and behaviours. A further strength is the use of established criteria (Moher et al., 2009) to guide the design, conduct and reporting of the meta-analysis.

The study also has a number of limitations. The MMP technique is relatively new and has been applied in a few studies only. The validity of the approach has also been questioned in the literature for confounding two sources of method bias (rating source, item characteristics) and ignoring two others (other item characteristics such as the number of anchor points or the measurement context) (N. P. Podsakoff et al., 2013). Against this, as well as being more straightforward to apply, the same article also found that an extension of the MMP technique addressing these issues by separately analysing the two confounded sources of method bias and included additional sources of bias produced virtually identical results. Finally, the current study is limited to just four health behaviours, therefore the extent to which the current findings apply to other health behaviours is not known and is a matter for future research.

Analyses revealed no evidence of publication bias. However, this needs to be considered in light of evidence that the results from the tests used here can become unreliable when high levels of heterogeneity are present, such as in the current analysis (Ioannidis & Trikalinos, 2007; Jin, Zhou, & He, 2015; Terrin, Schmid, Lau, & Olkin, 2003). It is worth noting however, that these conditions tend to produce an increase in the Type I error rate, whereas no evidence of publication bias was evident here. Further, we found no difference in the associations between TRA/ TPB model components and behaviour between published and unpublished studies. Previous reports have also downplayed the likelihood of significant publication bias in this literature (Armitage & Conner, 2001; McEachan et al., 2011; Schulze & Whittmann, 2003). Although future studies may wish to examine this issue in further detail.

Remedies for method bias

Based on the current assessment, some procedural remedies for method bias are suggested. First, given TRA/TPB variables are almost uniformly assessed using Likert-type self-report scales, avoiding self-reported assessments of corresponding behaviour is potentially the simplest method to avoid the effects of method bias as it precludes the psychological processes considered to drive the bias. However, given this is not feasible in many cases, researchers should aim to use contrasting methods of assessing behaviour that carry the least risk of bias, ideally using open-ended, continuous scales. Wherever possible, researchers should also examine discrete, concrete behaviours (e.g. the consumption of specific, health-promoting foods as opposed to 'healthy eating') as these broader categories appear to amplify the magnitude of method bias (some examples are provided in Supplementary File 7).

In a more general sense, perhaps the greatest remedy for avoiding method bias in TRA/TPB research would be to substantially revise current guidelines for measuring these models (Ajzen, 2002; Fishbein & Ajzen, 2010; Francis et al., 2004) which carry recommendations for measuring and testing the model that increase the risk of bias and the inflation of associations between model components and behaviour. In particular, the

requirements for scale compatibility and ensuring that the wording of the target behaviour is matched between predictor and criterion variables in terms of target, action, context and target appear likely to inflate correlations and reduce the practical significance of the model. Guidelines for measuring the TRA/TPB should be amended to address these issues of method bias.

Finally, it is worth noting that given the testing of social cognitive theories in health behaviour research has traditionally relied on data obtained from participants' self-reports, rather than direct observations of behaviour, it seems likely that significant method bias is also present in the cumulative evidence in support of other models. That these data are frequently used to estimate the associations between health behaviour and often abstract cognitive variables such as beliefs, estimates and evaluations adds further weight to this possibility. Future research should seek to examine the presence of method bias in other theories commonly applied in health behaviour research.

Conclusions

The current study aimed to estimate the impact of method bias on the associations between TRA/ TPB variables and a range of health behaviours. Taken together, our findings suggest that method bias significantly inflates associations in research examining the association between the TRA/TPB and health behaviour and poses a potentially serious validity threat to the findings reported in this field. When examined in further detail, the analyses indicate that both common source or rater and item characteristic effects were evident and there are strong reasons to believe that current guidelines for measuring and testing the theory may have amplified these effects. It is incumbent upon a theory to propose a test of its hypotheses that are independent of measurement artefacts. Based on the current analysis, it is not clear whether the TRA/TPB has achieved this for a range of different health behaviours.

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Table 1
Random-effects mean associations for included variables

Association	*k*	r_+	CI	*Q*	I^2
Intention-Behaviour	241	0.49	0.47-0.51	4435.87***	94.59%
Attitude-Behaviour	201	0.31	0.29-0.33	1906.24***	89.51%
SN-Behaviour	194	0.18	0.16-0.20	1540.72***	87.47%
PBC-Behaviour	217	0.32	0.30-0.34	2346.30***	90.79%

Note. *k* = number of effect sizes included in the analysis, CI = 95% confidence interval, *Q* and I^2 = tests of heterogeneity, r_+ = random effects average correlation, *** p<.001.

Table 2
Random-effects mean associations for included variables at each level of susceptibility to method bias.

	Attitude-Behaviour			SN-Behaviour			PBC-Behaviour			Intention-Behaviour		
Method Type (mean)	*k*	r_+	CI	*k*	r_+	CI	*k*	r_+	CI	*k*	r_+	CI
1-1.9	6	0.08	-0.09-0.25	4	0.03	-0.10-0.16	7	0.21	0.04-0.37	7	0.25	-0.01-0.46
2-2.9	104	0.28	0.25-0.30	100	0.14	0.12-0.16	109	0.33	0.31-0.36	123	0.46	0.43-0.49
3-3.9	87	0.35	0.32-0.39	86	0.23	0.19-0.26	98	0.31	0.27-0.34	107	0.53	0.50-0.56
4	4	0.33	0.18-0.47	4	0.31	0.12-0.48	3	0.34	0.14-0.51	4	0.48	0.23-0.68

Note. Behaviour method type: Each item comprising a given measure of behaviour was coded as system captured (1), behaviourally continuous (2), behaviourally anchored (3) or perceptually anchored (4). Multiple codings within measures were possible due to variation in method type across items. Following Sharma et al. (2009) and Podsakoff et al. (2013) a mean score was calculated based on those codings.

Table 3
Random-effects meta-regression analyses examining the impact of behaviour method type.

Variable	*B*	*SE*	*Z*	*p*	CI	
Intention-Behaviour (*k*=268)						
Method Type	0.09	0.03	3.77	<0.001	0.05	0.14
Intercept	0.30	0.06	4.56	<0.001	0.17	0.42
Attitude-Behaviour (*k*=201)						
Method Type	0.08	0.02	4.08	<0.001	0.04	0.12
Intercept	0.11	0.05	2.10	0.036	0.01	0.21
SN-Behaviour (*k*=194)						
Method Type	0.10	0.18	5.16	<0.001	0.06	0.13
Intercept	-0.06	0.05	-1.23	0.220	-0.15	0.04
PBC-Behaviour (*k*=217)						
Method Type	0.01	0.02	0.11	0.720	-0.03	0.05
Intercept	0.31	0.05	5.71	<0.001	0.20	0.42

Table 4
Random-effects meta-regression analyses comparing the impact of behaviour method type in cross-sectional and prospective associations.

Subgroup	Variable	*B*	*SE*	*Z*	*p*	CI	
Cross-sectional	Intention-Behaviour (*k*=100)						
	Method Type	0.11	0.04	2.91	0.004	0.04	0.19
	Intercept	0.25	0.10	2.46	0.014	0.05	0.44
	Attitude-Behaviour (*k*=78)						
	Method Type	0.07	0.03	2.07	0.040	0.01	0.14
	Intercept	0.14	0.09	1.59	0.112	-0.03	0.32
	SN-Behaviour (*k*=74)						
	Method Type	0.10	0.03	3.46	0.001	0.03	0.15
	Intercept	-0.07	0.07	-0.95	0.342	-0.20	0.10
	PBC-Behaviour (*k*=84)						
	Method Type	-0.01	0.04	-0.26	0.797	-0.08	0.06
	Intercept	0.36	0.09	3.91	<0.001	0.18	0.54
Prospective	Intention-Behaviour (*k*=141)						
	Method Type	0.09	0.03	2.49	0.013	0.02	0.15
	Intercept	0.32	0.09	3.62	<0.001	0.15	0.50
	Attitude-Behaviour (*k*=123)						
	Method Type	0.09	0.03	3.52	<0.001	0.04	0.14
	Intercept	0.09	0.07	1.42	0.157	-0.04	0.22
	SN-Behaviour (*k*=119)						
	Method Type	0.10	0.03	4.01	<0.001	0.05	0.15
	Intercept	-0.07	0.07	-1.05	0.293	-0.19	0.06
	PBC-Behaviour (*k*=133)						
	Method Type	0.02	0.03	0.57	0.569	-0.03	0.07
	Intercept	0.29	0.07	4.13	<0.001	0.15	0.42

Table 5
Random-effects meta-regression analyses examining the impact of behaviour method type in by target behaviour.

Behaviour	Constructs	*k*	Variable	*B*	*SE*	*Z*	*p*	CI	
PA	I-B	146	Method Type	0.10	0.03	3.02	0.003	0.04	0.17
			Intercept	0.34	0.07	4.53	<0.001	0.19	0.48
	A-B	117	Method Type	0.07	0.03	2.79	0.005	0.02	0.12
			Intercept	0.14	0.06	2.35	0.019	0.02	0.26
	SN-B	111	Method Type	0.05	0.02	2.51	0.012	0.01	0.10
			Intercept	0.03	0.05	0.55	0.586	-0.07	0.13
	PBC-B	123	Method Type	0.01	0.03	0.03	0.973	-0.06	0.06
			Intercept	0.35	0.08	4.61	<0.001	0.20	0.49
DP	I-B	24	Method Type	0.27	0.09	2.94	0.003	0.09	0.45
			Intercept	-0.25	0.26	-0.96	0.337	-0.77	0.26
	A-B	24	Method Type	0.24	0.05	4.53	<0.001	0.14	0.35
			Intercept	-0.31	0.15	-2.06	0.040	-0.61	-0.01
	SN-B	23	Method Type	0.16	0.04	4.23	<0.001	0.08	0.23
			Intercept	-0.23	0.11	-2.19	0.029	-0.44	-0.02
	PBC-B	22	Method Type	0.16	0.06	2.61	0.009	0.04	0.28
			Intercept	-0.12	0.18	-0.67	0.505	-0.46	0.23
FC	I-B	58	Method Type	0.02	0.05	0.27	0.783	-0.09	0.12
			Intercept	0.44	0.15	2.97	0.003	0.15	0.73
	A-B	47	Method Type	-0.02	0.05	-0.43	0.669	-0.13	0.08
			Intercept	0.38	0.14	2.64	0.008	0.10	0.66
	SN-B	47	Method Type	0.06	0.05	1.13	0.260	-0.04	0.16
			Intercept	0.05	0.14	0.36	0.718	-0.23	0.33
	PBC-B	58	Method Type	-0.03	0.04	-0.86	0.390	-0.11	0.04
			Intercept	0.38	0.11	3.42	<0.001	0.16	0.60
SP	I-B	13	Method Type	0.26	0.13	2.12	0.034	0.02	0.51
			Intercept	-0.18	0.38	-0.47	0.638	-0.93	0.57
	A-B	13	Method Type	0.08	0.13	0.61	0.542	-0.18	0.34
			Intercept	0.14	0.40	0.35	0.727	-0.64	0.92
	SN-B	13	Method Type	0.44	0.13	3.42	<0.001	0.19	0.69

Behaviour	Constructs	*k*	Variable	*B*	*SE*	*Z*	*p*	CI	
			Intercept	-1.04	0.39	-2.68	0.007	-1.80	-0.28
	PBC-B	14	Method Type	0.20	0.12	1.69	0.090	-0.03	0.42
			Intercept	-0.27	0.35	-0.75	0.451	-0.96	0.43

Note: *Behaviours* included were physical activity (PA), dietary patterns (DP), food choices (FC) and sun protection behaviours (SP); *Constructs* included were intentions (I), attitudes (A), subjective norms (SN), perceived behavioural control (PBC) and behaviour (B).

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3-7
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	9
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	8
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	8-9
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	9
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Supp File 2
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	9-10
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	10-11
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	10-11

Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	N/A
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	11
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	11

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	N/A
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	11-12
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	Supp File 3
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	N/A
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	N/A
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	N/A
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	Tables 1 & 2
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	N/A
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	Tables 3-5
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	15-20

Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	18-19
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	15-20
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	20

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: **www.prisma-statement.org**.

Supplementary File 2: Sample electronic search strategy (PsycINFO) for each review conducted.

(a) Physical activity

1. intent*.mp.
2. ("theory of reasoned action" OR "theory of planned behav*" OR "protection motivation theory" OR "social cognitive theory").mp.
3. ("physical activity" OR exercis* OR swimming OR jogging OR running OR cycling OR "active commuting" OR "keep fit" OR fitness OR gym OR sedentary OR inactivity).mp.

(b) Dietary patterns/ (c) Food choice behaviours

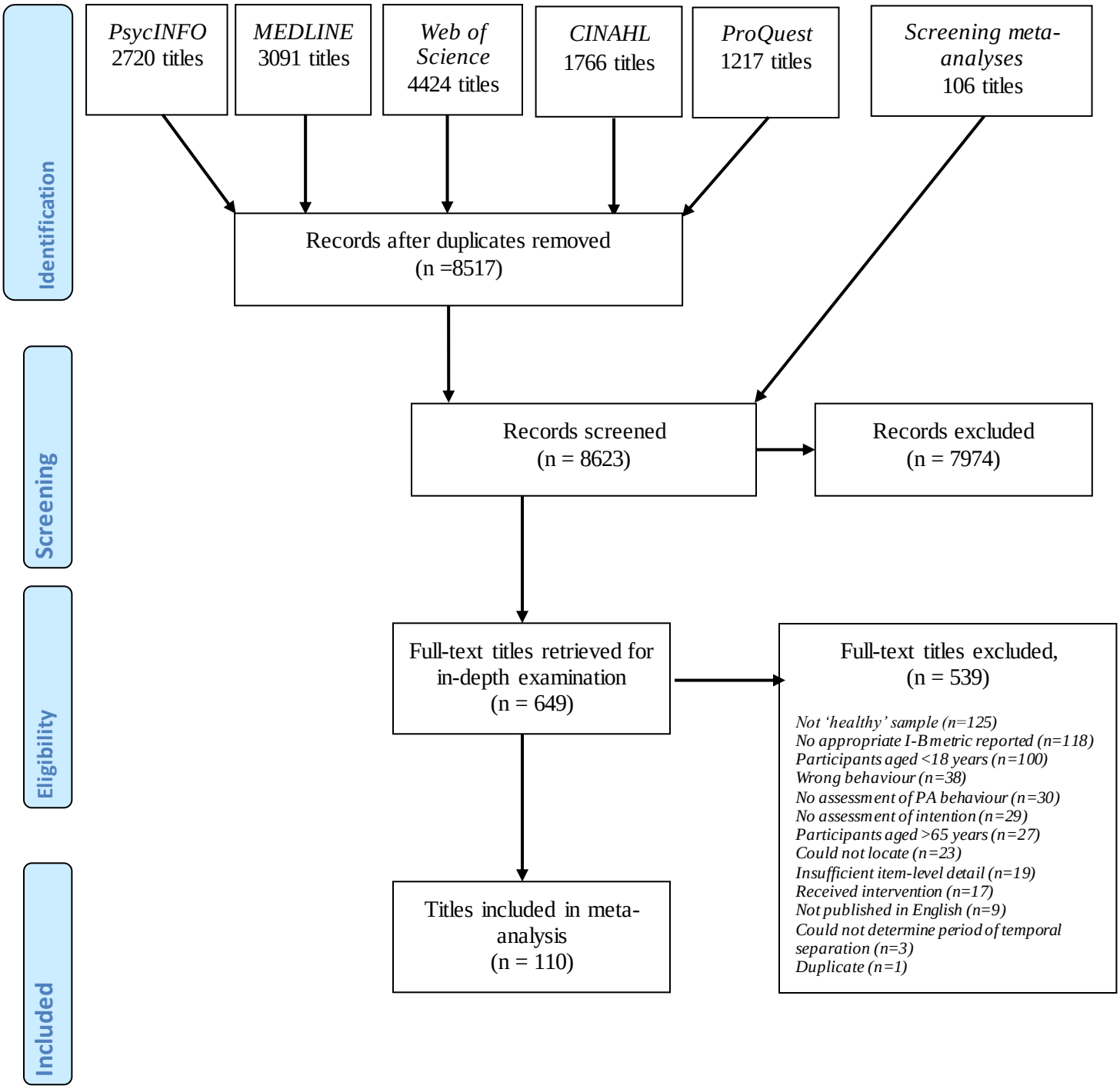
1. ("theory of planned behav*" OR "theory of reasoned action" OR intent*).mp.
2. (("perceived behavioural control" OR "perceived behavioral control" OR "subjective norm*" OR "attitude*") AND intent*).mp.
3. (eat* or diet* or consumption).mp.
4. (food or fruit* or vegetable* or fat or fibre or fiber or sugar* or snack*).mp.
5. 1 OR 2
6. 3 OR 4
7. 5 AND 6

(c) Sun protection behaviours

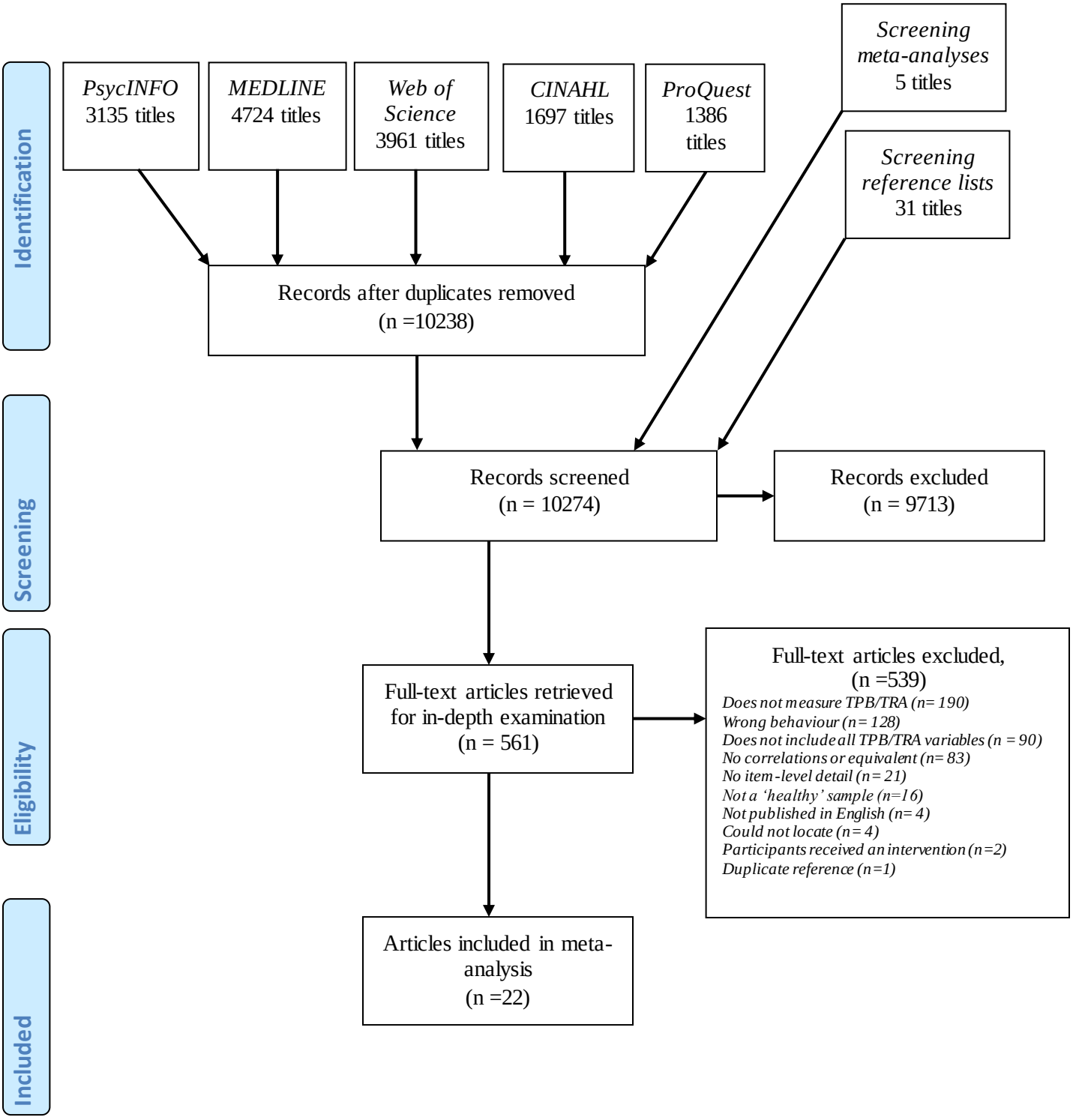
1. ("theory of planned behav*" OR "theory of reasoned action" OR intent*).mp.
2. (("perceived behavioural control" OR "perceived behavioral control" OR "subjective norm*" OR "attitude*") AND intent*).mp.
3. 1 or 2
4. ("skin cancer" or melanoma or tan* or sun*).mp.
5. 3 AND 4

Supplementary File 3: PRISMA flow charts for each included meta-analysis

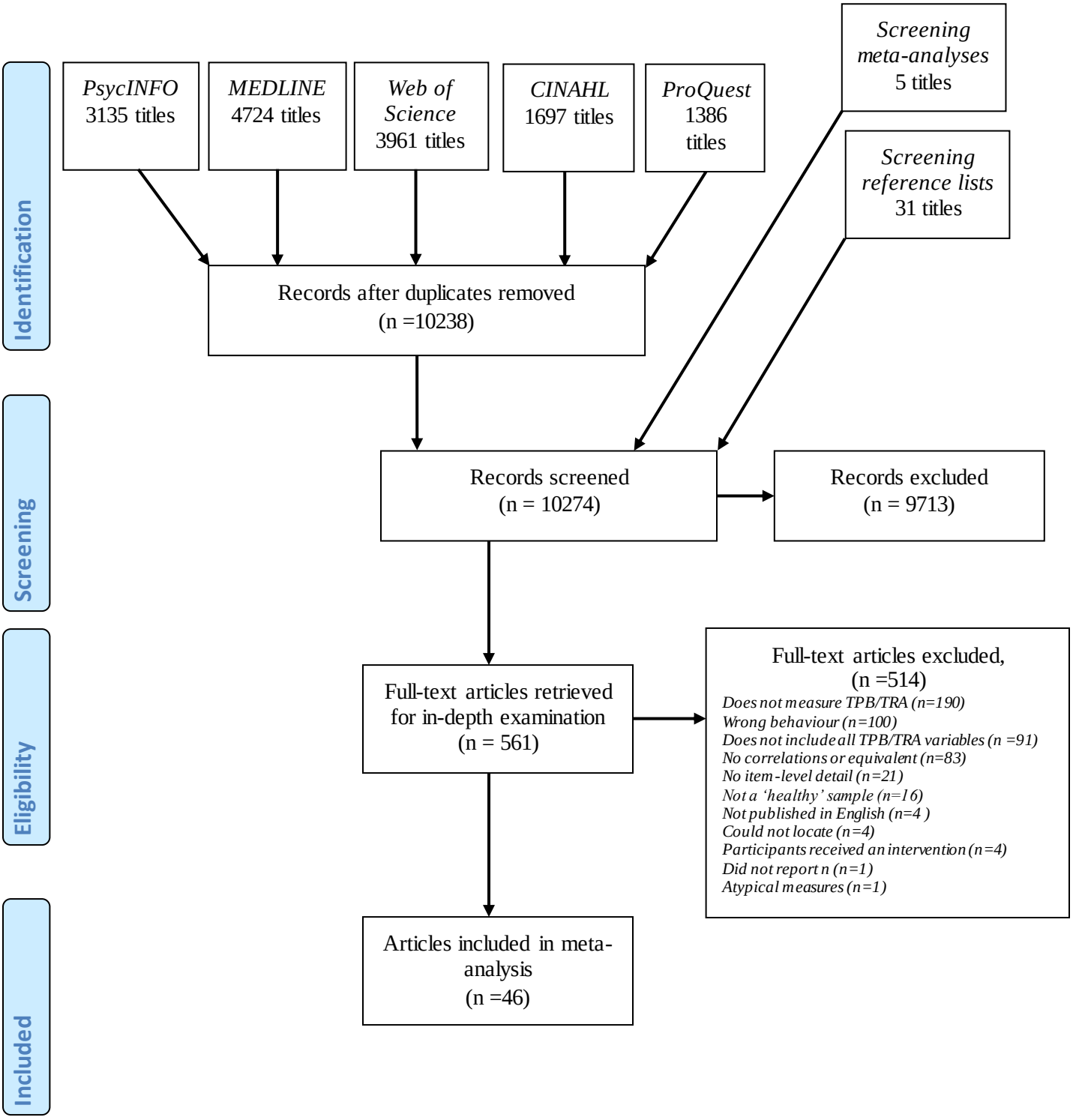
Supplementary Figure 1: PRISMA flow chart for physical activity studies



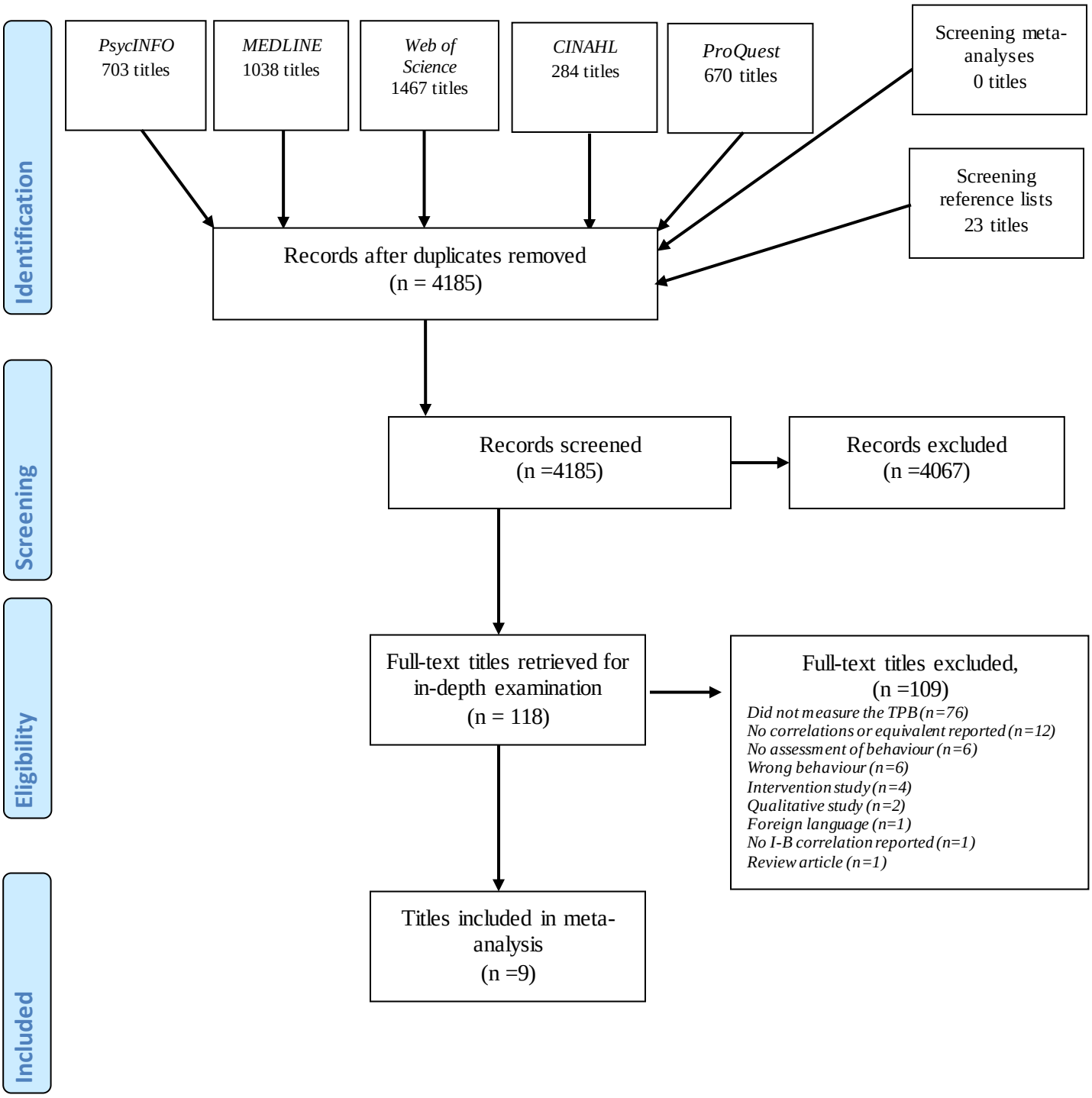
Supplementary Figure 2: PRISMA flow chart for dietary pattern studies



Supplementary Figure 3: PRISMA flow chart for food choice studies



Supplementary Figure 4: PRISMA flow chart for sun protection studies



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Supplementary File 5: Characteristics of studies included in the meta-analysis

Study	Behaviour	Article type	Country	N	Gender	Age
Abraham & Sheeran (2003)	Physical activity	Journal article	UK	254	-	20.9
Aghamolaei et al (2012)	Food choice	Journal article	Iran	321	62.9	43.7
Amireault et al (2008)	Physical activity	Journal article	Canada	300	64.0	37.7
Araujo-Soares et al (2013)	Sun protection	Journal article	UK	156	62.7	16.4
Armitage (2005)	Physical activity	Journal article	UK	94	56.4	37.6
Armitage & Conner (1999)	Dietary patterns	Journal article	UK	94	50.2	23.0
Astrom (2004)/ Astrom & Okullo (2004)	Food choice	Journal article	Uganda	1146	Not specified	15.8
Astrom & Rise (2001)	Dietary patterns	Journal article	Norway	709	51.0	25.0
Backman (1999)	Dietary patterns	Dissertation	USA	672	57.0	14-19
Baker (2001)	Dietary patterns	Dissertation	USA	279	70.0	14.9
Balian (2008)	Food choice	Dissertation	USA	93	54.0	11.0
Bellows-Riecken (2013)	Physical activity	Dissertation	Canada	65	43.1	22.8
Bellows-Riecken (2008)	Physical activity	Journal article	Canada	150	70.0	22.3
Berg et al (2000)/ Conner et al (2011)	Food choice	Journal article	Sweden	1096	52.0	11-15
Beville (2010)/ Beville et al (2014)	Physical activity	Dissertation	USA	621	67.8	20.2
Blanchard et al (2009a)	Food choice	Journal article	USA	511	49.7	19.8
Blanchard et al (2009b)	Food choice	Journal article	USA	176-237	56.9	20.2-20.6
Blanchard et al (2008a)	Physical activity	Journal article	USA	197-238	36.0 - 66.4	19.5- 20.5
Blanchard et al (2008b)	Physical activity	Journal article	USA	176-280	29.30-68.4	19.7-20.6
Blanchard et al (2007)	Physical activity	Journal article	USA	170-180	33.9-57.1	19.0-19.4
Blanchard et al (2004)	Physical activity	Journal article	USA	201-224	64.3-83.0	41.6 – 42.6
Bodimeade et al (2014)	Sun protection	Journal article	Australia	143	63.4	19.4
Bozionelos & Bennett (1999)	Physical activity	Journal article	UK	114	49.1	22.0
Branscum & Sharma (2014)	Food choice	Journal article	USA	69-98	100.0/ 0.0	10.3-10.5
Brickell et al (2006a)/ Brickell et al (2006b)	Physical activity	Journal article	Canada	162	61	23.2
Brouwer (2012)	Dietary patterms	Dissertation	USA	79	100	22.9
Brug et al (2006)	Food choice	Journal article	The Netherlands	627	50.9	37.5
Carter-Parker et al (2012)	Physical activity	Dissertation	USA	139	100	49.2
Caudroit et al (2014)	Physical activity	Journal article	France	157	65.6	36.7
Chatzisarantis et al (2008a)	Physical activity	Journal article	UK	444	58.6	19.1
Chatzisarantis et al (2008b)	Physical activity	Journal article	UK	146	55.5	20.6

Study	Behaviour	Article type	Country	N	Gender	Age
Chatzisarantis et al (2007)	Physical activity	Journal article	UK	180	51.7	19.1
Chatzisarantis & Hagger (2007) (Study 1)	Physical activity	Journal article	UK	226	51.3	19.2
Chatzisarantis & Hagger (2007) (Study 2)	Physical activity	Journal article	UK	292	51.4	19.5
Chatzisarantis et al (2005)	Physical activity	Journal article	UK	235	61.3	20.3
Churchill & Jessop (2011)	Food choice	Journal article	UK	139	77.7	21.2
Churchill et al (2008)	Food choice	Journal article	UK	315	65.7	38.5
Collins & Mullan (2011)	Food choice	Journal article	Australia	190	77.9	19.7
Conner et al (2010)	Physical activity	Journal article	UK	777	61.4	20.5
Conner et al (2007)	Physical activity	Journal article	UK	146	-	-
Conner & Abraham (2001)	Physical activity	Journal article	UK	138	84.6	21.8
Conner et al (2000)	Dietary patterns	Journal article	UK	407	-	37.4
Conroy et al (2010)	Physical activity	Journal article	USA	201	61.7	19.2
Corry (2008)	Physical activity	Dissertation	USA	133	51.9	19.6
	Food choice	Dissertation	USA	133	51.9	19.6
Courneya et al (1999)	Physical activity	Journal article	Canada	300	100	19.6
Courneya & McAuley (1994)/ Courneya (1993)	Physical activity	Journal article	Canada	170	52.4	20.3
Courneya (1994)	Physical activity	Journal article	Canada	85	51.8	20.1
Courneya & McAuley (1993)	Physical activity	Journal article	Canada	22-34	-	20.3
de Bruijn et al (2012a)	Physical activity	Journal article	The Netherlands	415	73.3	21.6
de Bruijn et al (2012b)	Physical activity	Journal article	The Netherlands	413	73.5	21.4
de Bruijn et al (2012c)	Food choice	Journal article	The Netherlands	109	78.0	22.6
de Bruijn & Van den Putte (2012)/ de Bruijn & Rhodes (2011)	Physical activity	Journal article	The Netherlands	538	71.6	21.2
de Bruijn (2010)	Food choice	Journal article	The Netherlands	538	53.7	21.2
de Bruijn et al (2009a)	Food choice	Journal article	The Netherlands	405	57.1	60.2
de Bruijn et al (2009b)	Physical activity	Journal article	The Netherlands	186	58.1	28.9
de Bruijn & Van den Putte (2009)	Food choice	Journal article	The Netherlands	312	65.3	14.6
de Bruijn et al (2008)	Dietary patterns	Journal article	The Netherlands	764	54.7	44.3
de Bruijn et al (2007a)	Food choice	Journal article	The Netherlands	521	53.7	34.5
de Bruijn et al (2007b)	Food choice	Journal article	The Netherlands	208	62.0	15.2
de Bruijn et al (2005)	Food choice	Journal article	The Netherlands	3859	55.2	14.8
de Bruin et al (2012)	Physical activity	Journal article	The Netherlands	499	49	44.3

Study	Behaviour	Article type	Country	N	Gender	Age
Dzewaltowski et al (1990)	Physical activity	Journal article	USA	254	52.4	-
Estabrooks & Courneya (1997)	Physical activity	Journal article	Canada	685	64.4	18.9
Fila & Smith (2006)	Dietary patterns	Journal article	USA	139	58.3	12.4
Fuchs (1996)	Physical activity	Journal article	Germany	142	50	52.2
Gardner & Lally (2013)	Physical activity	Journal article	UK	192	76	22.1
Githiri (2013)	Physical activity	Dissertation	USA	151	97.9	-
Godin et al (2010)	Physical activity	Journal article	Canada	1483	59.4	44.5
Godin et al (1993)	Physical activity	Journal article	Canada	347	62.5	-
Godin et al (1987)	Physical activity	Journal article	Canada	129	-	-
Hagger et al (2006a)/ Hagger et al (2006b)/ Harris & Hagger (2007)	Dietary patterns	Journal article	UK	250	56.4	24.6
Hagger & Chatzisarantis (2006)	Dietary patterns	Journal article	UK	250	56.8	24.9
Hagger & Chatzisarantis (2005)	Physical activity	Journal article	UK	523	61.6	21.1
	Dietary patterns	Journal article	UK	523	61.6	21.1
Hamilton et al (2012)	Physical activity	Journal article	Australia	206-252	0-100	35.5
Hoegy (2012)	Physical activity	Dissertation	Canada	170	58.8	55.6
Jackson et al (2003)	Physical activity	Journal article	UK	85	64	42.9
Jakul (2013)	Physical activity	Dissertation	Canada	183	65	18
Johnson (2006)	Physical activity	Dissertation	USA	308	63.3	18.6
Jones et al (2001)	Sun protection	Journal article	UK	113-376	54.0-60.9	-
Karimi-Shahanjarini et al (2012)	Food choice	Journal article	Iran	790	100.0	12-15
Kassem & Lee (2005)	Food choice	Journal article	USA	560	0.0	13-18
Kassem & Lee (2004)	Food choice	Journal article	USA	564	0.0	13-18
Kassem (2000)/ Kassem et al (2003)	Food choice	Dissertation/ Journal article	USA	710	100.0	13-18
Keatley et al (2012)	Physical activity	Journal article	UK	150	62.3	22.1
Kida & Astrom (1998)	Food choice	Journal article	Tanzania	309	46.5	16.2
Kim et al (2003)	Food choice	Journal article	USA	162	76.0	75.1
Kimiecik (1992)/ Kimiecik (1980)	Physical activity	Journal article	USA	332	46.4	39.1
Koring et al (2012)	Physical activity	Journal article	Germany	290	77.1	41.9
Kowal (2005)	Physical activity	Dissertation	Canada	149	100	51.8
Li & Chan (2008)	Physical activity	Journal article	USA	136	66	20.7
Lippke et al (2009)	Physical activity	Journal article	Germany	812	74.4	36.7
Louis et al (2007)	Dietary patterns	Journal article	Australia	137	80.0	18-29

Study	Behaviour	Article type	Country	N	Gender	Age
Lowe et al (2002)	Physical activity	Journal article	UK	365	61.6	43.4
Mahon et al (2006)	Food choice	Journal article	UK	1004	86.0	-
Martin et al (1999)	Sun protection	Journal article	USA	150	55.3	10.3
Masalu & Astrom (2001)	Food choice	Journal article	Tanzania	1090	32.0	26.4
McEachan et al (2010)	Physical activity	Journal article	UK	397	68.9	29.1
McLachlan & Hagger (2011)	Physical activity	Journal article	UK	172	69.2	30.8
Mitterer-Daltoe et al (2013)	Food choice	Journal article	Brazil	200	60.0	33
Molloy et al (2010)	Physical activity	Journal article	UK	903	62.6	22.2
Murillo (2013)	Physical activity	Dissertation	USA	405	100	38.5
Murnaghan et al (2010)	Dietary patterns	Journal article	Canada	287	51.0	12-16
Murray et al (2012)	Physical activity	Journal article	Canada	350	65.4	48.5
Myers & Horswill (2006)	Sun protection	Journal article	UK	85	70.6	20.5
Nejad et al (2004)/ Nejad et al (2005)	Dietary patterns	Journal article	Australia	77-256	100.0	20.7
Norman & Conner (2005) (Study 1)	Physical activity	Journal article	UK	102	80.4	20.8
Norman & Conner (2005) (Study 2)	Physical activity	Journal article	UK	125	52	21.4
O'Neal et al (2014)	Food choice	Journal article	USA	211	73.0	57-63
Okun et al (2003)	Physical activity	Journal article	USA	363	62	-
Okun et al (2002)	Physical activity	Journal article	USA	530	68	-
Onwezen et al (2014)	Food choice	Journal article	The Netherlands	491	50.0	44.7
Payne et al (2005)	Physical activity	Journal article	UK	286	30	-
Payne et al (2004)	Physical activity	Journal article	UK	296	30	-
	Dietary patterns	Journal article	UK	296	30	-
Payne et al (2002)	Physical activity	Journal article	UK	213	30	-
Plotnikoff et al (2012)	Physical activity	Journal article	Canada	1427	54.6	37.5
Plotnikoff et al (2009)	Physical activity	Journal article	Canada	1215-1582	52.6-53.7	39.0-40.0
Povey et al (2000a)	Food choice	Journal article	UK	144	70.0	41
	Dietary patterns	Journal article	UK	143	70.0	41
Povey et al (2000b)	Dietary patterns	Journal article	UK	234	70.0	38
Prell et al (2002)	Food choice	Journal article	Sweden	162	53.3	14
Presseau et al (2010)	Physical activity	Journal article	UK	137	77.3	21.0
Prior (1990)	Dietary patterns	Dissertation	Canada	177	0	29
Ranby (2009)	Physical activity	Dissertation	USA	160	100	63.0
Renner et al (2007)	Physical activity	Journal article	Germany	662	51.4	31.8

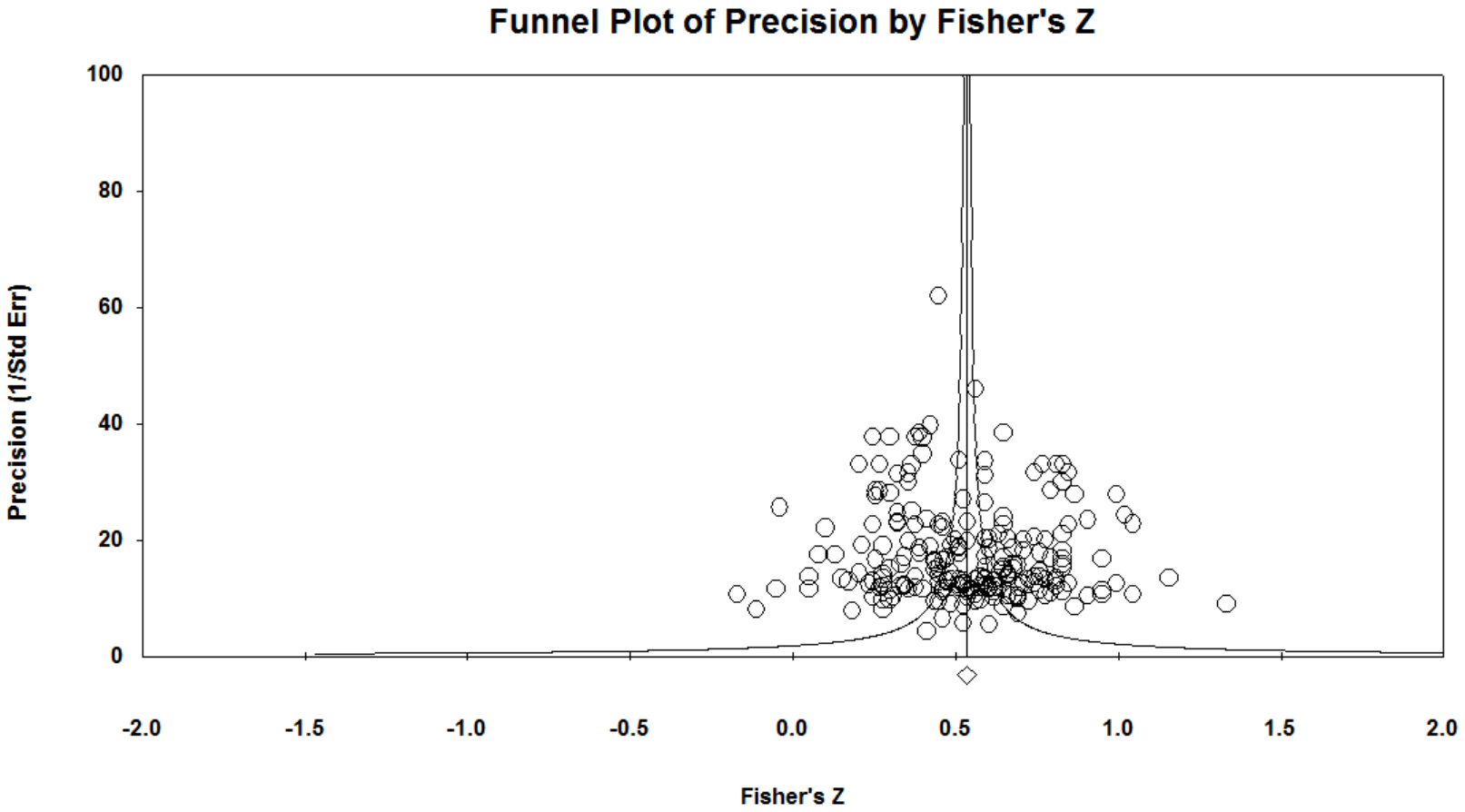
Study	Behaviour	Article type	Country	N	Gender	Age
Reuter et al (2010)	Physical activity	Journal article	Germany	265	16.4	44.9
Rhodes et al (2012)	Physical activity	Journal article	Canada	216	69.4	24.0
Rhodes et al (2010a)	Physical activity	Journal article	Canada	153	74	22.2
Rhodes et al (2010b)	Physical activity	Journal article	Canada	99-111	63-71	22.1-22.2
Rhodes & de Bruijn (2010)	Physical activity	Journal article	Canada	337	63.7	22.0
Rhodes & Blanchard (2008)	Physical activity	Journal article	Canada	174	61.5	41.0
Rhodes et al (2006a)	Physical activity	Journal article	Canada	220	80	20.4
Rhodes et al (2006b)	Physical activity	Journal article	Canada	230	70	22.3
Rhodes et al (2006c)	Physical activity	Journal article	Canada	420	81	21.5
Rhodes & Matheson (2005)	Physical activity	Journal article	Canada	241	80	20.4
Rhodes & Courneya (2005)	Physical activity	Journal article	Canada	585	72.8	20.1
Rhodes et al (2005)	Physical activity	Journal article	Canada	298	71	20.0
Rhodes et al (2003)	Physical activity	Journal article	Canada	300	71	19.9
Rhodes et al (2002)	Physical activity	Journal article	Canada	303	73.6	20.0
Richetin et al (2011)	Physical activity	Journal article	Italy	132	68.8	40.5
Richetin et al (2008)	Food choice	Journal article	Italy	75	69.4	23.8
Rise et al (2003)	Physical activity	Journal article	Norway	112	-	-
Rivis & Sheeran (2003)	Physical activity	Journal article	UK	225	-	-
Rodgers et al (2008)	Physical activity	Journal article	Canada	278	77.7	22.0
Sangperm (2008)	Dietary patterns	Dissertation	Thailand	191	70	13.3
Sassen et al (2010)	Physical activity	Journal article	The Netherlands	1298	67.3	32.8-44.8
Schneider (1994)	Physical activity	Dissertation	USA	111	61	-
Scholz et al (2008)	Physical activity	Journal article	Switzerland	354	81.4	37.0
Scott et al (2009)	Physical activity	Journal article	Canada	158-179	63.7	22.0
Sharifirad et al (2013)	Food choice	Journal article	Iran	521	46.8	16.3
Sheeran & Abraham (2003)	Physical activity	Journal article	UK	185	-	-
Sheeran & Orbell (2000)	Physical activity	Journal article	UK	163	-	-
Sills (2006)	Physical activity	Dissertation	USA	147	63	39.5
	Dietary patterns	Dissertation	USA	147	63	39.5
Sjoberg et al (2012)	Food choice	Journal article	USA	258	80.6	-
Skår et al (2008)	Physical activity	Journal article	UK	903	62.6	22.2
Smith & Biddle (1999)	Physical activity	Journal article	UK	155	43.2	36.0

Study	Behaviour	Article type	Country	N	Gender	Age
Smith (1996) Study 2	Physical activity	Dissertation	Canada	58	58	20.5
Smith (1996) Study 3	Physical activity	Dissertation	Canada	419-511	80	35.1
Smith (1984)	Physical activity	Dissertation	USA	850	47.1	43.4
Tak et al (2013)	Food choice	Journal article	The Netherlands	323	54.1	58.3
Tak et al (2011)	Food choice	Journal article	The Netherlands	970	46.0	14.1
Taut & Baban (2012)	Physical activity	Journal article	Turkey	35	74.3	20.2
Terry & Hogg (1996)	Sun protection	Journal article	Australia	133	54	20.6
Terry & O'Leary (1995)	Physical activity	Journal article	Australia	135	55.4	20.3
Thomson et al (2012)	Sun protection	Journal article	Australia	116	100	35.2
Towler & Shepherd (1991)	Food choice	Journal article	UK	288	61.5	42
Tuu et al (2008)	Food choice	Journal article	Vietnam	612	59.3	32
Tweed (2008)	Physical activity	Journal article	USA	111-283	10.5-14.3	-
Verbeke & Vackier (2005)	Food choice	Journal article	Belgium	429	66.9	40.6
Verplanken (2006)	Food choice	Journal article	Norway	128	64.1	-
Wang (2011)	Physical activity	Journal article	USA	517	70.6	20.3
Wang (2007)	Physical activity	Dissertation	USA	315-516	68.4-70.6	20.3-21.1
White et al (2014)	Sun protection	Journal article	Australia	577	51.8	39.7
White et al (2008)	Sun protection	Journal article	Australia	734	61.1	14.5
Yordy & Lent (1993)	Physical activity	Journal article	USA	284	67.2	19.4
Yordy (1992)	Physical activity	Dissertation	USA	284	67.3	19.5
Zoellner et al (2012)	Food choice	Journal article	USA	119	66.0	41.4

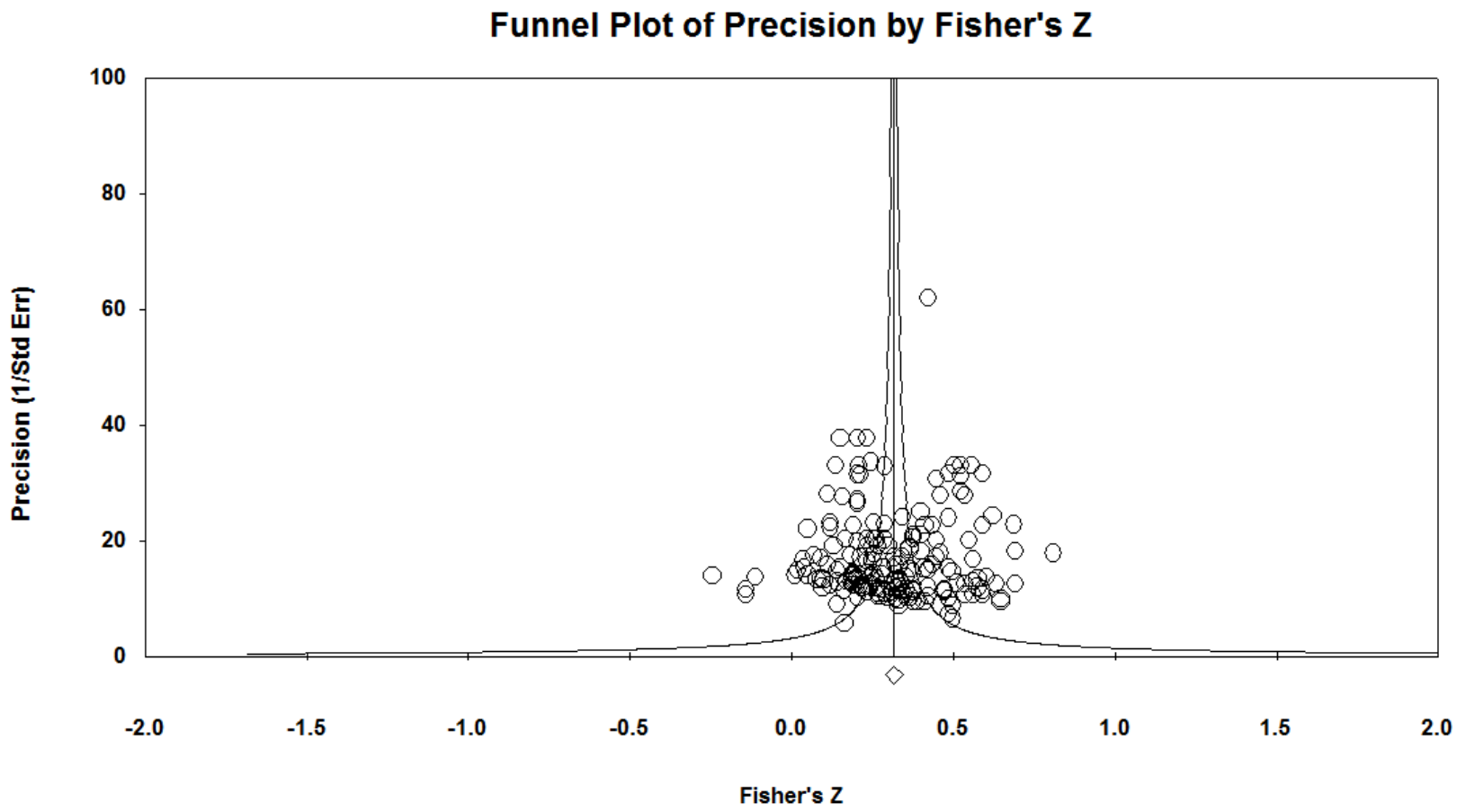
Notes: **Behaviour** indicates which meta-analysis the study was included in; **Article type** indicates whether the citation was a peer-reviewed journal article or unpublished dissertation; **Country** indicates where the research was conducted; **N** indicates the number of participants included in analyses; **Gender** is the proportion of females included in the sample; **Age** is an indicative figure, provided in years, based on mean, median or range as available.

Supplementary File 6: Funnel and forest plots

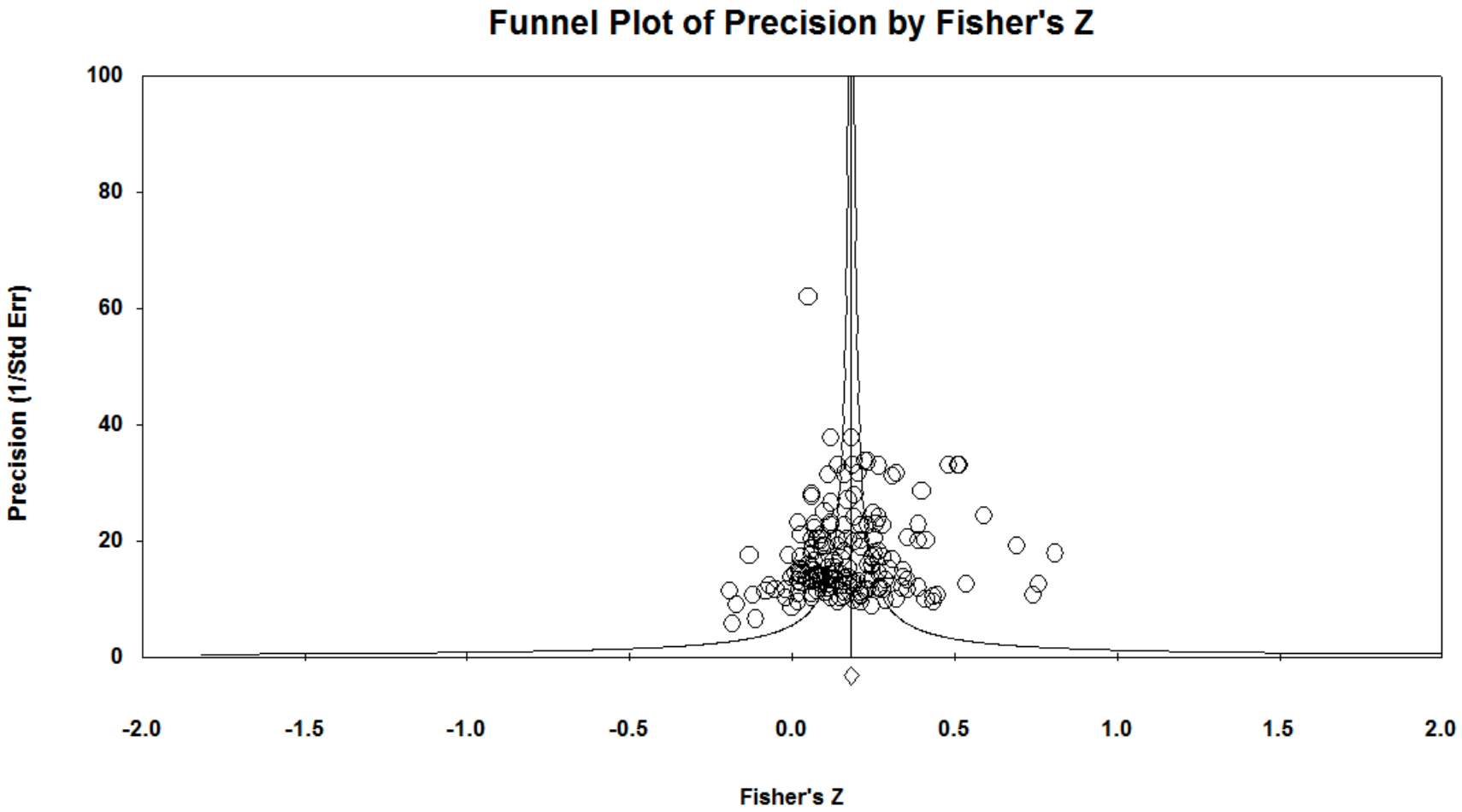
Supplementary Figure 5: Funnel plot for the association between intention and behaviour



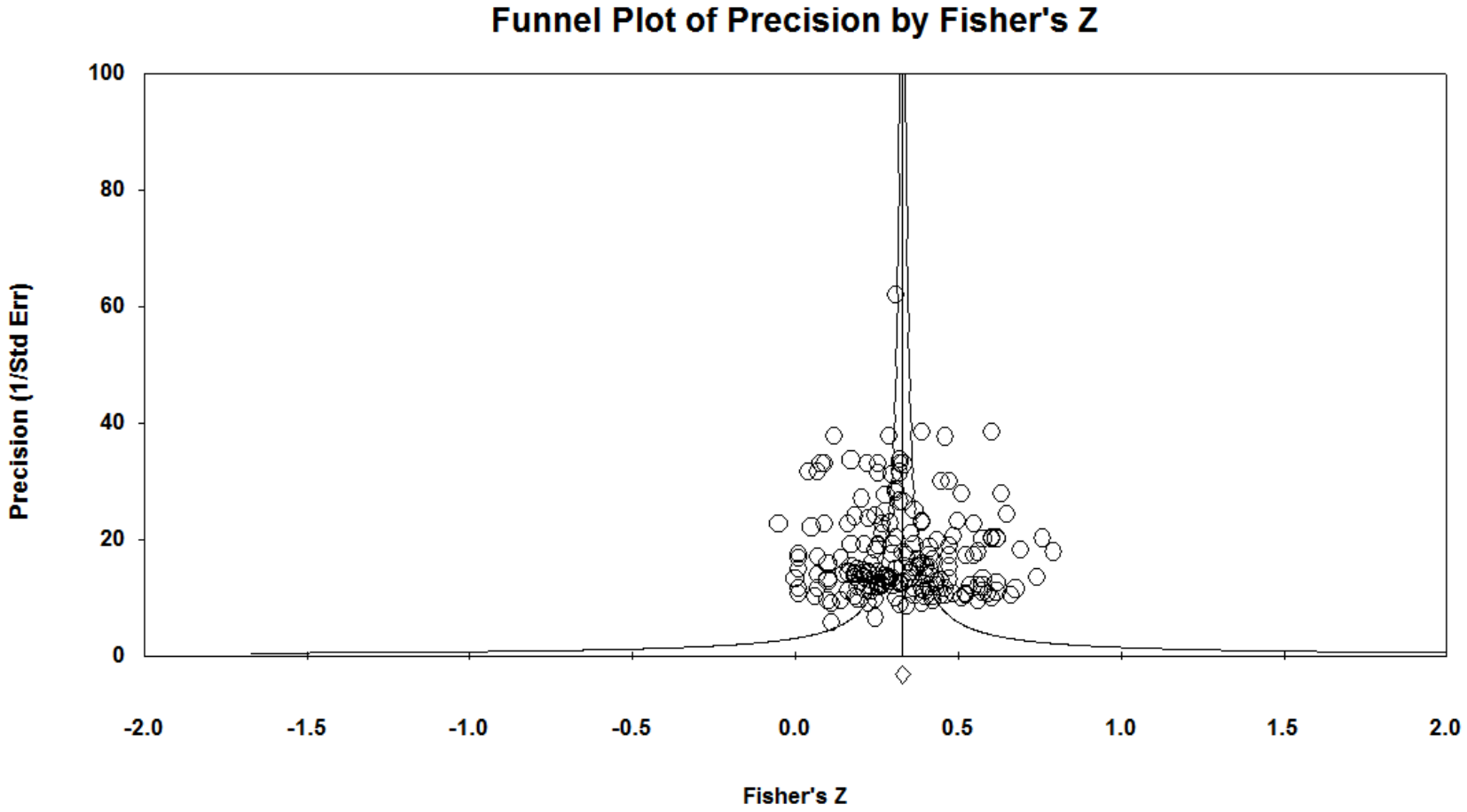
Supplementary Figure 6: Funnel plot for the association between attitude and behaviour



Supplementary Figure 7: Funnel plot for the association between subjective norms and behaviour



Supplementary Figure 8: Funnel plot for the association between perceived behavioural control and behaviour



Supplementary File 7

Sample items for measuring behaviour with varying levels of risk from method bias

Given that, within the context of TRA/TPB studies, antecedent variables are almost universally assessed using items assessed using perceptually anchored Likert-type scales, researchers should aim to avoid using this response scale when measuring behaviour.

For example:

"I ate vegetables regularly over the last 2 weeks," (rated from *strongly disagree* to *strongly agree*).

Should be avoided in favour of a behaviourally continuous item e.g. "*I ate vegetables X times per day over the last 2 weeks*."

Alternatively, a behaviourally anchored item could be used, although this would increase the likelihood of method bias compared with a behaviourally continuous item, e.g. "*How often did you eat vegetables over the last 2 weeks,"* (rated from *never* to *frequently).*

Wherever possible, researchers should also examine discrete, concrete behaviours.

For example, items such as "*Over the past month, how many days did you eat healthily"* should be avoided in favour of more specific behaviours, e.g. "*Over the past month, how many days did you eat vegetables"* or "*how many days in the past month have you consumed at least two pieces of fruit per day*".